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Application Status of Bending Technology for A Curved Aluminum Profile in Automobile Body

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Abstract: In the automotive industry, the lightweight structure of the vehicle is a key factor in improving fuel efficiency, reducing emissions and improving the dynamic performance of the vehicle. Because of its light weight, high strength and good corrosion resistance, aluminum profiles have been widely used in modern automobile design. Among them, the curved profile of the automobile body is applied to the body structure, suspension system components, chassis and frame components, interior structure components, powertrain components, external decorative parts, roof beams and other key structures.

Keywords: curved profiles; aluminum alloy; automotive body; bend technique; springback

1. INTRODUCTION

Extrusion forming process is widely used to prepare the profile products with complex section shape and high specific strength[1]. Compared with casting, forging and other processing methods, extrusion forming has obvious advantages in production efficiency, material utilization and environmental friendliness, and is suitable for rapid continuous mass and high-precision production[2]. At the same time, severe plastic deformation can improve the microstructure and mechanical properties of the metal.

The curved aluminum profiles are widely used in a variety of important components of automobiles, including suspension components, chassis and frame components, interior structural components, powertrain components, exterior trim parts, roof beams. With the advantages of lightweight, green and low-carbon, it opens up a broad market scenario. The curved profiles play an important role in the battery box, body frame, door and roof structure of new energy vehicles[3]. Traditional fuel vehicle manufacturers are also looking to curved aluminum profiles instead of steel to achieve weight reduction in their vehicles[4]. The ultimate pursuit of vehicle performance has prompted the use of high-strength, low-weight curved profiles to improve vehicle performance. Global restrictions on vehicle emissions and government incentives are also boosting the lightweight materials market.

The "extrusion + bending" process is a key technology in modern automobile manufacturing, which can produce lightweight parts with complex shapes and high strength requirements. The traditional curved profiles are formed by extruding straight profiles first and then bending them, which belongs to the secondary plastic forming process of "extruding first and bending later". The more common cold bending processes are tensile bending, roll bending, winding bending and additional device assisted bending.

2. PROFILE BENDING TECHNIQUE

2.1 Roll-bending Technique

As shown in Figure 1, roll bending is realized by installing regularly arranged, shape-adjustable rollers, whose movement in the horizontal and vertical directions causes the material to bend and deform[5]. Roll bending can easily and quickly construct a three-dimensional stretch bending profile forming surface, saving the mold manufacturing costs. However, this method has a large radius of rebound, which is prone to cause defects such as wrinkles in the inner layer of the profile, and it requires multiple corrections by the personnel at a later stage, which greatly increases the labor cost.

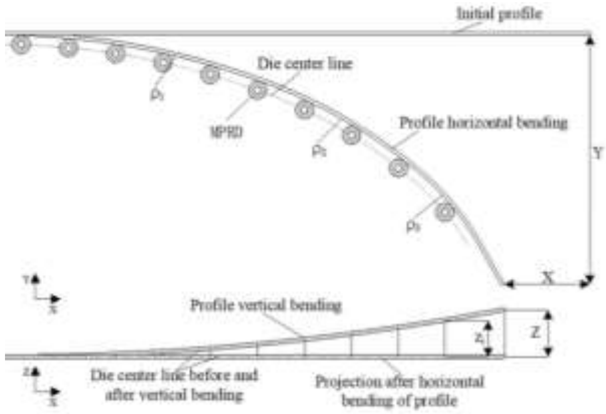

Figure. 1 Roll-bending device[5]

2.2 Stretch-bending Technique

Stretch bending mainly adopts the pre-bending tension loading method[6], which is shown in Figure 2. Firstly, the profile is placed into the rotary stretching machine, the pre-stretching force is applied to make the profile reach the yield strength, and then under the action of the bending mold, the profile generates the movement and thus bending. Stretch bending can process large-sized products with complex shapes, and the resulting springback is small and easy to operate. However, due to the preloading method, stretch bending products are prone to cross-sectional deformation, cracking, wrinkling and other defects.

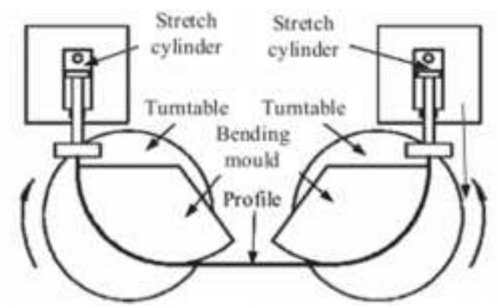

Figure. 2 Stretch-bending device[6]

2.3 CNC Winding Bending Technique

The CNC places the profile to be bent in the clamping die, which is driven to rotate at a certain speed to realize profile bending[7]. As can be seen in Figure 3, the pressure mold can prevent the material from bulging during the bending process, and the anti-wrinkle mold can prevent the profile from wrinkling on the inside. However, due to more constraints, the bending process is complex, when the parameter design is not accurate, it is easy to produce the profile bending outer thinning, elliptical distortion and other defects, and will be accompanied by a large springback.

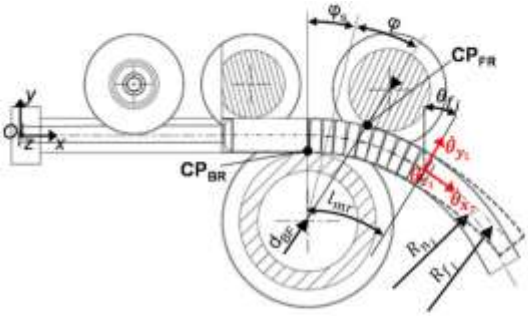

Figure. 3 CNC winding bending device[7]

2.4 Hydroforming Bending Technique

Hydroforming bending is employed for processing hollow profiles[8], which is shown in Figure 4. The process involves first injecting liquid into a sealed tube and setting the fluid pressure to the designed value. Subsequently, the sealed tube is placed between upper and lower molds, and the tube is bent by closing the upper mold. During hydroforming bending, the deformation of the sealed cross-section is restrained under internal pressure support, which generates an axial tensile force on the sealed tube. Moreover, after the pressure is released, increasing the fluid pressure within the tube can prevent defects such as internal wrinkling from occurring. Due to the simplicity of hydroforming bending, requiring only a bending die and press, this method is particularly suitable for bending large diameter tubes. However, it may lead to drawbacks such as low section forming precision and a large springback radius.

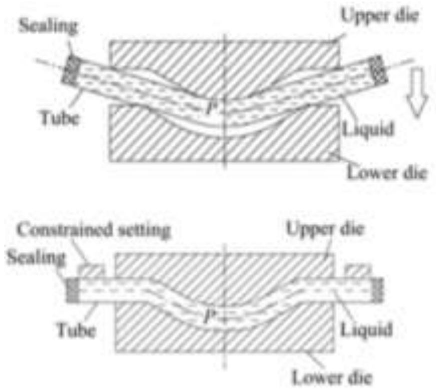

Figure. 4 Hydroforming bending device[8]

2.5 Annular Disc-guided bending

It can be seen that in Figure 5, by adding a choke pin to the extrusion die, the material produces an uneven flow when passing through the choke pin, thereby extruding the curved profile[9]. By changing the length of the choke pin entering the die, profiles with different curvature radius can be obtained.

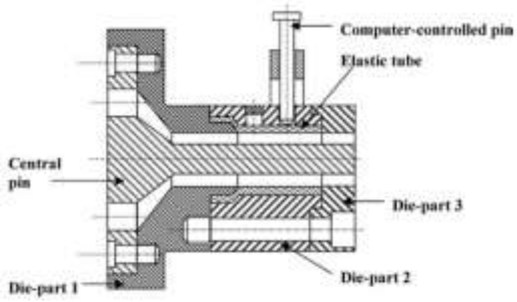

Figure. 5 Annular disc-guided bending device[9]

2.6 Choke Pin Bending Technique

An inclined die extrusion process is proposed in Figure 6[10]. The exit of the die is designed to be inclined at a fixed Angle, which makes the material produce a poor speed and extrudes profiles with different curvature radii. The results show that the curvature of extruded profiles increases exponentially with the increase of die Angle and decreases linearly with the increase of tube wall thickness, regardless of section shape and size. With the increase of die height and width, the curvature of extruded profile decreases.

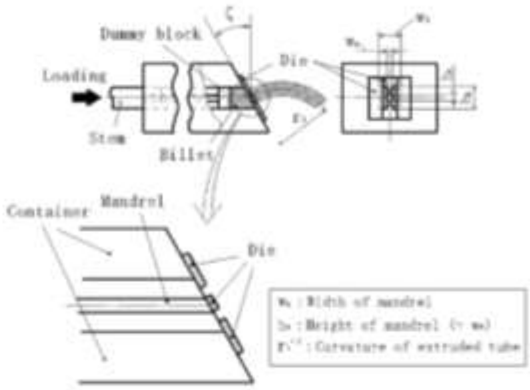

Figure. 6 Choke pin bending device[10]

3. CONCLUISONS

In summary, bending aluminum profiles of various cross-section shapes can be prepared by using various profiles bending arc processes, but the current process commonly used in production has the following shortcomings:

Limited accuracy: the traditional bending process is difficult to achieve high-precision bending Angle and radius, especially in the bending of complex shapes.

Surface damage: During the bending process, the outer surface of the aluminum profile may appear scratches, wrinkles or cracks, affecting the appearance and performance of the product.

Tool wear: Molds and tools used in traditional bending processes will accelerate wear due to friction and pressure, increasing production costs.

Low production efficiency: due to the limitations of precision and surface quality, the production speed of the traditional bending process is relatively slow and is not suitable for mass production.

Material limitations: Some aluminum alloy materials may not be suitable for traditional bending processes, because they are prone to fracture or deformation during bending.

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